R329 - 2 (ZDC PMT) Lifetime issues

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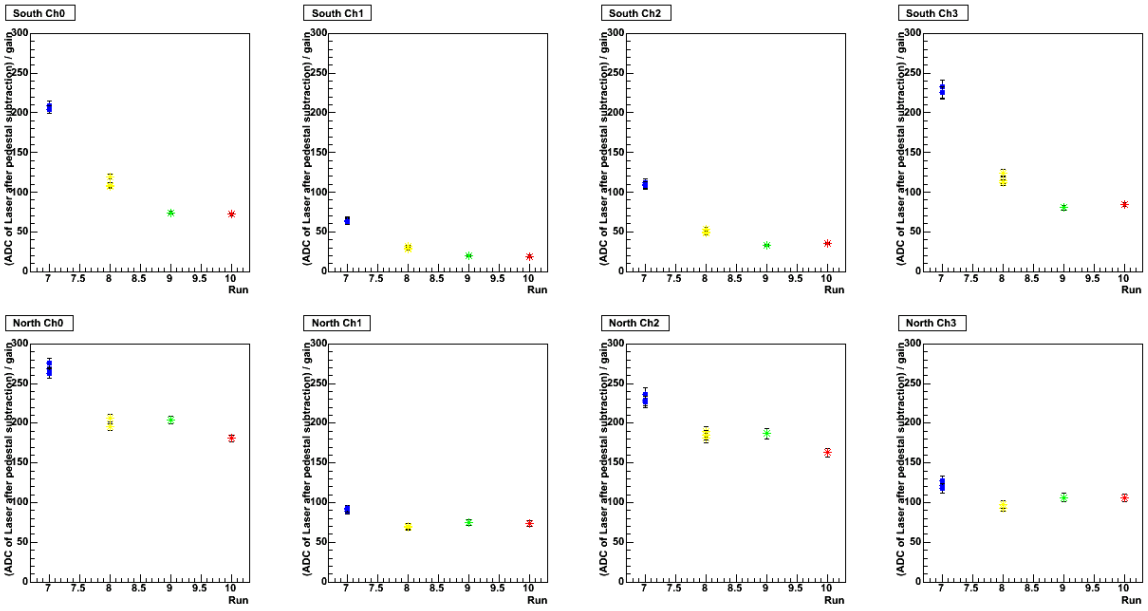
The ZDC pulse height has gone down in both arms during the last couple of runs by as much as a factor of 2. This can be seen from the trend plots of led pulse height vs. run number in the following plot:



Since both the LED peaks and physics data (neutron peaks) show the same change, we don't think this is a result of radiation damage to the modules. Instead we suspect either degradation of the photocathode response in the PMTs or a problem in the electronics (the Maryland module). We don't see any real change in performance (ie width of the neutron peak is the same as in the past) once we raise the HV from the nominal setting.

So we obtained the Hamamatsu lifetime measurements for the R329-2 which are attached below. One caveat is this is not the identical PMT but they say lifetime should be similar.

From this plot it seems you lose 30% in cathode efficiency after 10,000 hrs (at 100μA anode current). So we expect a problem after an integrated anode current of

```
<< Units`
```

```
Lifetime = Convert[100 Micro Ampere * 10 000 Hour, Coulomb]
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```
3600 Coulomb
```

That's a huge integrated current! Lifetimes of some of Hamamatsu's more exotic PMT's can be as low as 100 C or even .1 Coulomb. Note that Hamamatsu likes to quote lifetime in integrated Anode current. Their model is that the photocathode is damaged by heavy stuff released when accelerated electrons hit the gas or the anode. Some people do it differently. For example we did for the PHENIX EMCAL. But we think we should stick with their model.

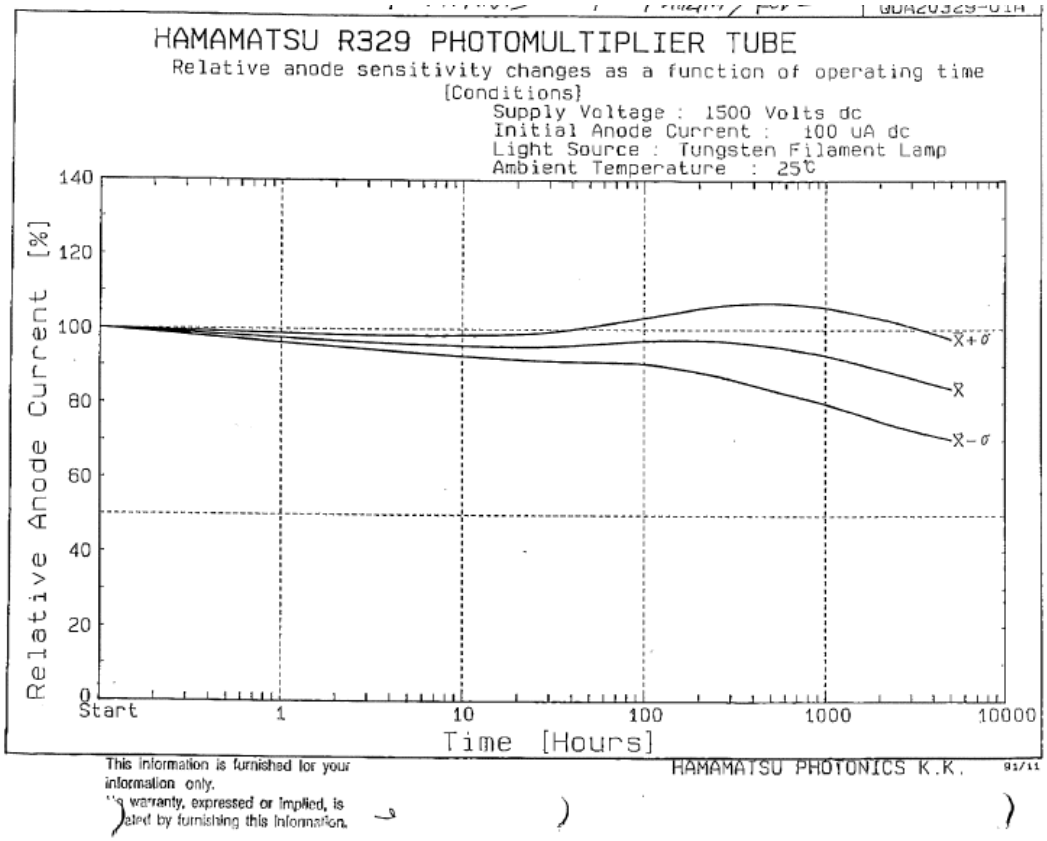
What would we expect for Run-9? Let's take a very rough average signal of 50 pico Coulomb, an effective cross section of 20 mbarn, a luminosity of 10^{31} and a duty factor of 0.3 for 4 months.

```
PHENIX = Convert[0.3 * 4 Month * 10^31 * 20 * 10^-27 * 50 * Pico Ampere, Coulomb]
```

```
31.536 Coulomb
```

% / Lifetime

0.00876



So we saw some evidence for signal loss while Hamamatsu lifetime data indicate we have perhaps another order of magnitude to go but there are also uncertainties in this simple calculation.

In order to clarify what is going on we returned a couple of affected tubes to Hamamatsu and asked them to test both photocathode and anode response. As can be seen from Hamamatsu's report below, the decrease in Anode response, is completely consitent with the damage pattern we see in the South ZDC.

Dear Sebastian White:

We received 2 pc(s). of H1161-50 on 08/06/2010 of which we are returning 2 pc(s).

Following is the explanation for this decision:

Ref. No. : Measurement Cost PO#000181610
Customer Part No. : N/A
Serial No. : RC9136, RC8575
Qty. : 2

We received 2 pcs. of H1161-50 from you to check the performance of them, and forwarded them to our main factory in Japan for evaluation. They checked the cathode sensitivity, the anode sensitivity, and the dark current at 1500, 1750, 2000 V. Please refer to the following.

		SK	SKb	SP	IDB
				(2000V)	(2000V)
		[uA/lm]	-	[A/lm]	[nA]
RC8575	Original	95.2	10.9	1940	1.6
	Retest	102	11.5	865	2.2
RC9136	Original	92.5	10.6	1900	2.7
	Retest	95.6	11.3	836	6.9

V-Sp

		SP			
		1500	1750	2000	[V]
Returned	RC8575	84	297	865	[A/lm]
Returned	RC9136	81	284	836	[A/lm]

V-Dark

		IDB			
		1500	1750	2000	[V]
Returned	RC8575	0.44	0.91	2.2	[nA]
Returned	RC9136	0.32	1.2	6.9	[nA]

The cathode sensitivity has a similar value to the shipment. However, the anode sensitivity goes down by around 50 %. The dark current meet the specification completely.
In addition, they found that the value of the base resistor was 51 kohm each. It is the current specification. However, when these tubes were shipped to you, the specification was 100 kohm.
It seems that you changed the resistor of the divider circuit, but we are not absolutely sure as these PMTs are very old.
At any rate, with 51 kohm resistors, the power consumption of the divider circuit is large. To avoid the effect of heat, the PMTs should be operated by 2000 V.
Also, they repaired the housing case for RC9136, because we created the damage due to the improper handling. They checked it after repairing, and it works properly.

Recommendation: It is almost certain that the STAR problem with their ZDC which they solved by removing their ZDC and replacing it with modules from the BRAHMS experiment is, in fact, due to the same PMT aging problem. Fortunately Dana Beavis has already given us 2 of their unused tubes that we bought at the beginning of the project. We plan to use those tubes to replace the most severely affected tubes in PHENIX. Both collaborations should start to track beam losses around the ZDC in coordination with a log of ZDC base currents. Surprisingly Run 9 where we sweated most over losses wasn't that bad for the tubes.